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Promising Site Cleanup Technology

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by

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16. ABSTRACT

Within the EPA Office of Research and Development, the Solid and Hazardous Waste Research Division (SHWRD), Municipal Environmental Research Laboratory, has the responsibility for the control development program in support of "Superfund." The SHWRD research and development program has been organized to correspond with the "Superfund" legislation, i.e. the Oil and Hazardous Materials Spills Branch deals with removal actions (emergency), and the Disposal Branch deals with remedial actions. Due to the special demands of "Superfund," the normal research and development process of concept development, laboratory evaluation, pilot testing, and field demonstration cannot be followed. "Superfund" is a 5-year program requiring answers today. Thus, the program is one of technology assessment to determine cost and effectiveness, adaptation of technologies to the uncontrolled waste site problem, field evaluation of technologies that show promise, development of guidance material for the EPA Office of Emergency and Remedial Response (OERR), technical assistance to OERR, and EPA Regional Offices. An overview of the program is presented.

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INTRODUCTION

Within the EPA Office of Research and Development, the Solid and Hazardous Waste Research Division (SHWRD), Municipal Environmental Research Laboratory, has the responsibility for the control development program in support of "Superfund." The SHWRD research and development program has been organized to correspond with the "Superfund" legislation, i.e. the Oil and Hazardous Materials Spills Branch deals with removal actions (emergency), and the Disposal Branch deals with remedial actions. Due to the special demands of "Superfund," the normal research and development process of concept development, laboratory evaluation, pilot testing, and field demonstration cannot be followed. "Superfund" is a 5-year program requiring answers today. Thus, our program is one of technology assessment to determine cost and effectiveness, adaptation of technologies to the uncontrolled waste site problem, field evaluation of technologies that show promise, development of guidance material for the EPA Office of Emergency and Remedial Response (OERR), technical assistance to OERR, and EPA Regional Offices. A brief overview may clarify our program goals.

Removal (Emergency) Actions

This program can be divided into three major areas of activity: (1) Personnel Health and Safety, (2) Demonstration of Equipment, and (3) Chemical Countermeasures. The goal of the personnel health and safety program is to develop protective equipment and procedures for personnel working on land or underwater in environments which are known or suspected to be immediately dangerous to life or health, so that such personnel can conduct operations related to investigating, monitoring, or cleaning up of hazardous substances. In addition, it is hoped that this equipment and procedures will result in greater worker efficiency and lower operational cost, as well as improvement of personnel safety.

Our major effort on removal technology centers on demonstration of equipment designed for hazardous spill control. This equipment is being modified, adapted, and field tested. Examples, which I will discuss in more detail later, include a mobile incinerator, carbon regenerator, and soils washer.

Presented at Conference entitled "Superfund Update: Cleanup Lessons Learned," October 11-12, 1983, Schaumburg, Illinois.

The chemical countermeasures program is concerned with the use of chemicals and other additives that are intentionally introduced into the open environment for the purpose of controlling the hazardous contaminants held within, e.g. soil or surface and groundwater. However, the use of such agents poses a distinct possibility that the release situation could be made worse by the application of an additional chemical or other additive. Therefore, the objective of this activity is to define technical criteria for the use of chemicals and other additives at release situations of hazardous substances such that the combination of released substances plus the chemical or other additives, including any resulting reaction or change, results in the least overall harm to human health and to the environment. I will further explain this program later.

Remedial Actions

We have divided the remedial action program into three major areas of activity: (1) Survey and Assessment of Current Technologies, (2) Field Demonstration and Verification of Techniques, and (3) Site Design Analysis.

We feel there is much to be learned from the remedial actions that have already been conducted by federal and state governments and industry. Thus, we have an ongoing and continuing effort to review and evaluate techniques that are being used and have been used in the past at uncontrolled hazardous waste sites. Our analysis includes defining the site-specific problem, determining the problems associated with implementing the technique, determining the effectiveness, and identifying the cost. We have found the data base on many of the early remedial actions to be inadequate for a good evaluation; however, those actions taken in the last few years are providing much better information. The survey results and the data used in our technical handbooks will be published on a regular basis. We hope to computerize this data base in the future.

Techniques that have a potential for being cost-effective are being field verified. These field evaluations are conducted in two ways. We will actually field test a technique that looks very promising or we will conduct an intensive field evaluation of a technique being installed as part of a remedial action. In practice, our research program provides the additional resources needed to obtain an array of operational monitoring data which will be adequate to fully evaluate and assess a technique. An example of a field test conducted by us is the "Block Displacement" isolation method which I will discuss later. An evaluation of a slurry trench installed at a "Superfund" site in New Hampshire is an example of a field evaluation.

Our third area is an outgrowth of the first two, that is, the development of technical handbooks to be utilized by the planners and designers of remedial actions. Below is a listing of the handbooks that have been prepared or are in progress:

- Remedial Action at Waste Disposal Sites - 6/82
- Reviewers of Proposed Hazardous Waste Remedial Actions - 9/83

- o Cover Design and Installation - 11/84
- o Fixation/Solidification of Waste in Surface Impoundments - 11/84
- o Decontamination of Buildings, Structures, and Construction Sites - 5/85
- o Slurry Trench Design and Installation - 3/84
- o Procedures and Techniques for Controlling the Migration of Leachate Plumes - 3/84

Superfund Problem Areas

To facilitate this presentation, I would like to divide the "Superfund" program into four problem areas. This list is not intended to be all encompassing, but it will be used to focus my discussion on "promising site cleanup technology."

Problem areas

- o Drums/containers filled with hazardous waste
- o Soils/sludges/sediments
- o Ultimate destruction
- o Groundwater

Following are several descriptive summaries of research projects which we have recently completed or have currently underway in these areas.

Drums/Containers

We have all seen pictures of hazardous waste sites with piles of deteriorating drums oozing hazardous waste. SHWRD supported a project that reviewed the current state-of-the-art on handling drums at uncontrolled sites and recommended areas of future research needs. This report is being combined with an OERR drum-handling effort into a drum-handling handbook that should be available in June 1984. In general, the study found that the current procedures and drum-handling equipment are adequate.

SHWRD has been pursuing a new technique for drum encapsulation that shows promise. The following is a description of that activity.

Polymeric Overpack for 55-Gallon Drums

A prototype full-scale process and equipment have been developed and evaluated for encapsulating corroding 55-gallon drums of hazardous waste. The overpack system will provide a means for reducing the health and safety hazards associated with containing and transporting leaking 55-gallon drums and other containers or waste forms from an uncontrolled site to a final disposal site.

The overpack process utilizes friction-welding (spin-welding) to fuse a polyethylene (PE) cover onto a PE receiver into which a 55-gallon drum of waste has been inserted. Friction welding involves rotating one piece of plastic in contact with another stationary plastic piece. In the case of the overpack process, the cover is rotated while the receiver containing the waste is clamped in a stationary position. Friction

causes the contact surfaces of both pieces to melt. Rotation is stopped and the pieces are pressed together. The melted polyethylene solidifies and the two pieces are fused together, creating a seal. The overpacks are fabricated by rotomolding a 1/4-inch thick container from PE and sectioning the container into a receiver and cover.

The thickness of the overpack is controlled by varying the amount of powdered PE placed into the rotomolder. The top (cover) is designed with ribs to accommodate the spin-welding tool. The overpack is approximately 85 gallons in size and large enough to accept drums that may be partially deformed. The friction welding machine consists of a hydraulically-operated plate used to spin the PE cover. Other features include the appropriate hydraulics, valves, controls, switches, a platform, and features necessary to position and seal the cover to the container. One operator is required to man the machine during the welding operation. The equipment is designed to be easily transported from site to site. Appropriate fork lifts and other drum-handling equipment are required at facilities handling the drums and the overpack system. Overpacks are designed for easy stacking and can be handled with conventional drum-handling equipment.

Rotomolded PE overpacks have been successfully sealed using the friction-welding equipment. Sealed overpacks have been subjected to hydrostatic burst tests and have exceeded the performance of similar size metal drums. Specimens under tensile testing of the weld have failed at points other than the weld. Leach testing of the welded overpacks has shown that the containers are leak tight. Details of the test results, including micrographic examination of the seals and crush testing, are available.

Additional expected performance data can be extrapolated from previous studies and from the fact that PEs and other plastics are well characterized. They provide a unique combination of excellent chemical stability, flexibility, and mechanical toughness. Expected mechanical performance of the overpack system can be increased by filling the void between the drum and the PE overpack. This can be done with sands, soil, absorbant, off-spec portland cement, or other inert material.

The value of the friction-welded seal is in its capability to remain leak-tight under stresses that will normally force conventional screw caps, clamps, and similar seals to break or open.

An evaluation of the overpack process is being planned to prove the equipment performance and the ability to produce a leak-tight seal. Approximately 85-100 drums of waste will be overpacked. Random samples will be subjected to testing to further evaluate the performance of the overpack system. Because of the requirement to process 85-100 drums, the equipment as designed and constructed is essentially full-scale. However, the evaluation will also point to design modifications that will improve the performance. One example is the operation of multiple spin-welding plates from a single unit. This would increase processing capabilities.

Data from the evaluation and previous encapsulation studies will provide sufficient information to make the plastic overpack process available for use in several ways. It was specifically conceived as a superior overpack to decrease the health and safety hazards associated with the containment, transportation, and disposal of leaking drums from uncontrolled sites. However, it has potential application as an acceptable long-term containment system for the disposal of hazardous waste from small quantity generators. Additionally, because of its superior seal, the system could be used for the safe, long-term storage of hazardous waste that might be recovered in the future.

Soils/Sludges/Sediments

Soils, as well as sludges and sediments contaminated with hazardous materials, have been one of the most complex and perplexing problems to face the cleanup practitioner. For example, 500,000 cubic yards of soil contaminated with dioxin are reported to be located in Missouri. In the case of dioxin-contaminated soil, a concentration as low as one part per billion is of concern. At almost all hazardous waste sites some soil pollution has occurred due to the storage and processing of waste, or as leakage from tanks, drums, and lagoons. Landfills and capping have been the most popular control technology used, however, these techniques do not always give the assurance of complete and final control that the public desires. Many innovative concepts have been proposed to treat contaminated soils, sludges, and sediments, including:

- Inplace leaching
- Inplace biological degradation of hazardous components, including the use of "Superbugs"
- Inplace chemical treatment
- Removal/treatment, e.g. Gamma Radiation, ultraviolet, chemical treatment, and wet air oxidation
- Land treatment or composting
- Soil washing (solvent extraction)
- Thermal treatment, e.g. incineration, molten salt, and microwave plasma
- Fixation, e.g. organic polymers

I would like to discuss a few of the promising techniques that SHWRD is pursuing.

Mobile Soils Washing System

SHWRD has developed a Mobile Soils Washing System that can be used to treat excavated soils at sites where in-situ washing is ineffective or not applicable, and where hauling of excavated soil to a landfill is not cost-effective or is undesirable because of environmental or institutional barriers.

The system is capable of extracting contaminants from soils--"artificially leaching" the soil using a water-based cleaning agent--and thereby enabling operators to leave the treated soil on-site. To accomplish this, the soil is passed through a rotating drum screen water knife soil scrubber where soil lumps are broken apart by intense jets of water, and

chemicals are tripped from soil particles. The resulting soil slurry is fed into a four-stage countercurrent chemical extractor. Each stage consists of a mixing, froth-flotation cell connected in series with hydrocyclones which centrifugally separate solids from liquids. The soil particles are agitated repeatedly in washing fluid and are progressively decontaminated as they flow through each stage. The cleansed soil is then returned to the site. The extracted hazardous contaminants are separated from the washing fluid using physical/chemical treatment procedures (flocculation, sedimentation, carbon adsorption, etc.). The cleaned washing fluid is recirculated while the separated and concentrated contaminants are disposed of by appropriate means.

The Soils Washing System is capable of processing 4 to 18-yd^3 of contaminated soil per hour, depending on the soil particle size and the nature of the contaminant.

Current activity includes the shakedown of the system and complete full-scale, controlled-condition tests using water-based wash fluids to ensure that the system operates properly and performs within a delineated range of soil and pollutant parameters. Plans also call for an investigation of the feasibility of using the Soils Washing System with organic solvents to extract dioxin from wet excavated soils.

Chemical Countermeasures

One key countermeasure is the use of chemicals and other additives that are intentionally introduced into the open environment for the purpose of controlling the hazardous contaminant. The use of such agents, however, poses a distinct possibility that the release situation could be made worse by the application of an additional chemical or other additive. Therefore, the objective of this R&D activity is to define technical criteria for the use of chemicals and other additives at release situations of hazardous substances such that the combination of released substance plus the chemical or other additive, including any resulting reaction or change, results in the least overall harm to human health and to the environment.

The Chemical Countermeasures Program (CCP) has been designed to evaluate the efficacy of in-situ treatment of large volumes of subsurface soils, and large, relatively quiescent waterbodies. For each situation, the following activities are planned: (a) a literature search to develop the body of existing theory and data; (b) laboratory studies on candidate chemicals at small scale to assess adherence to theory and define likely candidates for full-scale testing; (c) full-scale, controlled-condition, reproducible tests to assess field operation possibilities; and (d) full-scale tests at a site-of-opportunity. After the data are developed for a given chemical use situation, a technical handbook will be prepared.

To date, efforts have concentrated on soils-related activities and have taken this aspect of the program through the laboratory studies to a point where a decision will be made on continuation into full-scale controlled-condition testing. The laboratory studies were used to determine whether significant enhancements to the in-situ cleanup of chemically contaminated soils with standard water washing techniques

could be obtained by using aqueous surfactants. The addition of the surfactant mixtures was designed to improve the solvent properties of the water and enhance the removal of adsorbed chemical contaminants.

Based on the results of the literature search, three pollutant groups (mixtures of compounds) were selected for laboratory testing on soils:

1. High molecular weight polynuclear aromatic and aliphatic hydrocarbons (distillation fraction of Murban crude oil)

2. PCB mixture in chlorobenzenes (Aroclor^{R} 1260 transformer oil)

3. Di-, tri-, and pentachlorophenols

Shaker table agitation studies were performed to determine the maximum cleanup efficiency under equilibrium conditions using water washes and a combination of 2 percent each of Hyonic PE90 (now known as NP90 by the manufacturer), and Adsee 799 (Witco Chemical) surfactants. After the most efficient surfactant concentrations were determined, column studies were initiated to evaluate soil cleanup efficiency under gravity flow conditions. In general, overall soil cleanup approaching the 90 plus percent level was attained with the intermediate molecular weight aliphatic and aromatic hydrocarbons, the PCB mixtures, and the chlorinated phenol mixtures. Results appear to support additional larger scale studies and plans are being discussed to construct a soils test facility at EPA's OHMSETT facility in New Jersey.

Pending the availability of supplemental FY'84 funds and a positive decision on construction of the soils test facility, SHWRD would like to expand the controlled condition testing program to include the investigation of surfactants and other chemicals for decontamination of dioxin-laden soils.

Asphalt Encapsulation

Asphalt encapsulation techniques, consisting of mixing heated asphalt with a sludge material, are being considered as a treatment option (Figure 1). Coating (or microencapsulation) of the sludge particles would improve the leachate quality and could act to reduce the hazardous nature of some compounds in the sludge. Additional heating of the mixture could act to thermally degrade the compound, e.g. nitroaromatic and RDX compounds.

Research to date has included (1) an evaluation of existing asphalt encapsulation techniques for hazardous wastes, (2) an evaluation of alternative heating/mixing systems, (3) review of the properties of various asphalt products which may be used, (4) laboratory experiments on the temperature and holding times required for thermal breakdown of the various compounds present in certain sludges, and (5) preliminary design of a pilot mixer/heating system. Our first studies have been with a sludge containing trinitrotoluene (TNT), hexahydro-1,3-5-trinitro-1,3,5-triazine (RDX), and other nitroaromatics. A synthetic sludge with

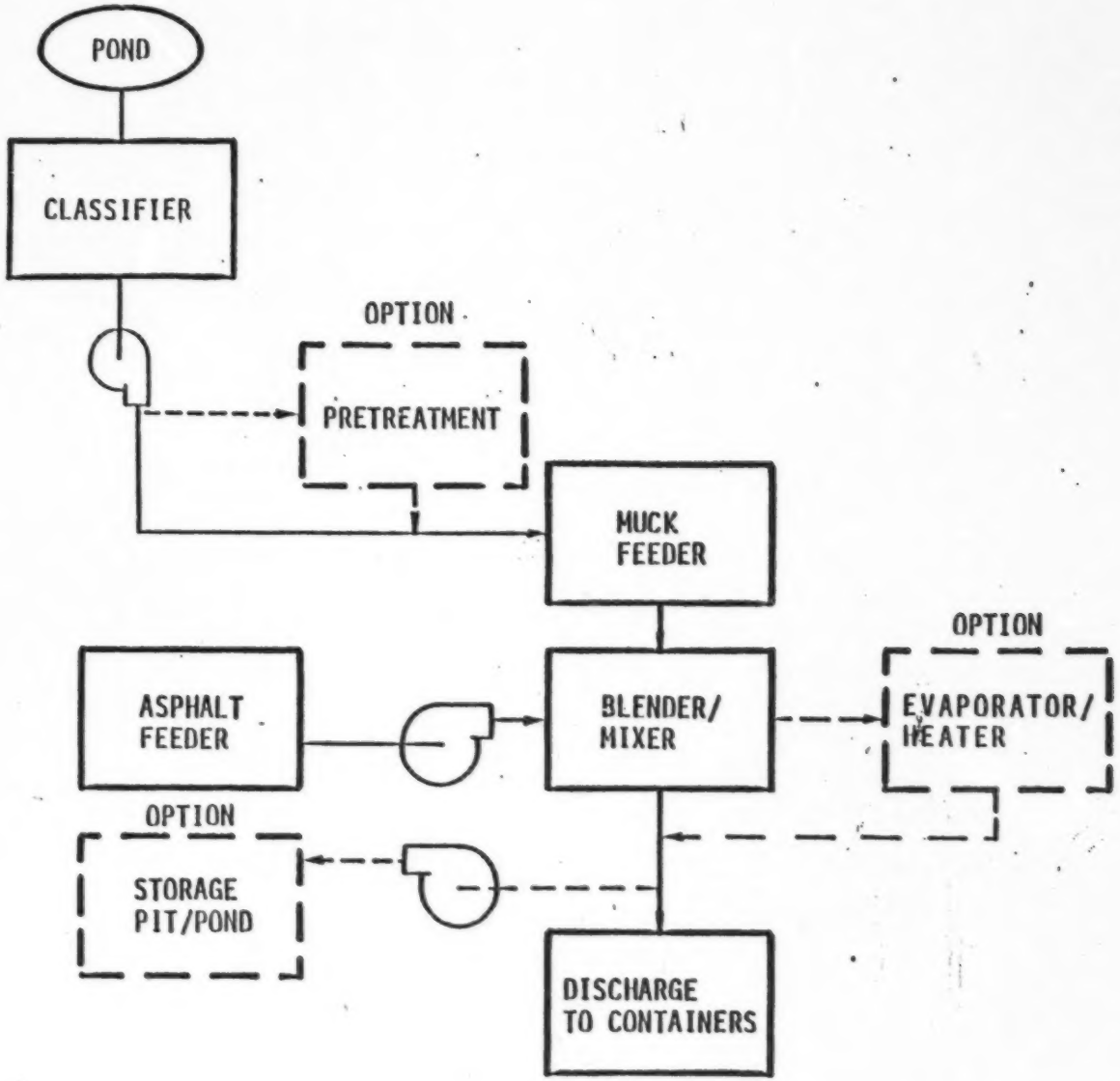

Figure 1. Sludge Encapsulation Process

physical properties similar to the actual sludge will be used during the initial runs and during modifications of the pilot system. Actual lagoon sludge will be used in the field for the final testing.

Factors which are being evaluated include residence times required for both mixing and thermal breakdown, mobility of the hazardous system, safety considerations, batch feed vs. continuous feed designs, and through-put rates.

A preliminary study has been completed on the selection of an asphalt/sludge mixer. The two most promising mixers are the pug mill and static pipe. Final tests are being made to select a mixer for pilot studies.

A laboratory evaluation was conducted to assess the temperature and holding times required for breakdown of the nitroaromatics and RDX in sludge. This information is necessary to design the mixer system and to determine if thermal degradation occurs at temperatures below the flashpoint of available asphalts. A total of 17 heating tests were conducted, representing four temperatures (150, 200, 250, and 300°C) and four residence times (5, 10, 15, and 20 minutes) plus one sample heated for 2 hours at 100°C. The results, however, do indicate that thermal degradation of approximately 90 percent of the explosive and nitroaromatic compounds occurs at 250°C. The results are based solely on the heating of the sludge. Further testing will be required in order to determine whether various types of asphalt in combination with the sludge result in equally low levels of explosive and nitroaromatic compounds. These tests are underway. In addition, studies will be conducted on utilizing the asphalt encapsulation technique on other organic waste. Following these tests, pilot-scale evaluation will be conducted.

Ultimate Destruction

The preferred approach to uncontrolled hazardous waste sites is conversion of the hazardous material to a nonhazardous form. Several techniques have been mentioned earlier and include: thermal treatment, gamma radiation and ultraviolet treatment, chemical treatment, and biological treatment. Whereas, some of these techniques are state-of-the-art for some waste, others are in the research, development, and field evaluation stage.

Thermal treatment is being extensively studied by EPA. The Industrial Environmental Research Laboratory (IERL) has a comprehensive program evaluating fixed incineration systems and the utilization of cement kilns and industrial boilers to burn organic hazardous waste. In addition, they are evaluating high-technology processes such as wet air oxidation, molten salt, and microwave plasma. SHWRD has concentrated its efforts on mobile incineration units that can be taken directly to the uncontrolled sites. Two types of units are under study--mobile and modular.

Mobile Incineration System

SHWRD has developed a mobile incineration system designed for field use to destroy hazardous organic substances collected from cleanup operations at spills or at uncontrolled hazardous waste sites. EPA develops such equipment to actively encourage the use of cost-effective, advanced technologies during cleanup operations.

The mobile incineration system is designed to meet the requirements of TSCA and RCRA and provide state-of-the-art thermal detoxification of long-lived, refractory organic compounds, as well as debris from cleanup operations. Hazardous and toxic substances that could be incinerated include compounds containing chlorine and phosphorus--for example, PCB's, kepone, dioxins, and organophosphate pesticides, which may be in pure form, in liquids, in sludges, or in soils.

The mobile incinerator consists of four trailers with specialized equipment. (See attached Fact Sheet.) In the kiln, organic wastes are fully vaporized and completely or partially oxidized at 1800°F. Incombustible ash is discharged directly from the kiln, while off-gases are passed through the secondary combustion chamber (SCC) at 2200°F. Here, the thermal decomposition of the contaminants is completed. The flue gas exits from the SCC and is then cooled from 2200°F to approximately 190°F in a water spray quench elbow. Excess water is collected in the quench elbow sump, and the cooled gases then pass to the third trailer. Here, submicron particulates are removed from the gas stream as it passes through the cleanable high-efficiency air filter (CHEAF), and acid gases are neutralized in the mass transfer (MX) scrubber. Gases are drawn through the entire incineration system by an induced draft (ID) fan and are discharged from the stack. A monitoring system is used to analyze the flue and stack gases for combustion components (carbon monoxide (CO), carbon dioxide (CO_2), and oxygen (O_2)), and emission components (oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and total hydrocarbons (THC)) to ensure regulatory compliance and high thermal combustion efficiency.

To date the operational and performance aspects of the mobile incineration system have been evaluated during 37 days of shakedown and TSCA/RCRA compliance trial burn. The performance of the system has been exceptional in terms of destruction and removal efficiency (DRE) of test organics and the ability to meet air emission requirements. The DRE for test compounds, di-, tri-, and tetrachlorobenzenes, carbon tetrachloride, and PCB's ranged from 99.9991 percent to 99.9999 percent for all test runs (RCRA requirements, >99.99 percent). The combustion efficiency ($CO_2/(CO_2 + CO)$) x 100 exceeded 99.999 percent for all tests (TSCA requirements, >99.9 percent). The removal of HCl produced from the combustion of chlorinated test compounds exceeded 99.88 percent (RCRA requirements, >99 percent). The emission rate of particulate matter was less than 80 mg/dscm, (RCRA requirements, <180 mg/dscm).

Now that the construction and initial testing of the mobile incinerator has been completed, it will be tested under field conditions. The EPA is currently considering various sites as candidates for the demonstration tests. These sites include: (1) Times Beach, Missouri,

EPA

FACT SHEET

United States
Environmental Protection
Agency

April 1982

EPA's Mobile Incineration System for Cleanup of Hazardous Substance Spills and Waste Sites

EPA's Office of Research and Development has recently completed construction of a mobile incineration system designed for field use to destroy hazardous organic substances collected from cleanup operations at spills or at uncontrolled hazardous waste sites. EPA develops such equipment to actively encourage the use of cost-effective, advanced technologies during cleanup operations. Other systems, including two devices for treating contaminated soils, both after excavation and **in-situ**, are currently under development. Once an item of hardware is complete, it is tested under field conditions. After testing, plans, specifications, and other information are made available publicly for the purpose of encouraging commercialization of the new technology. Numerous systems, including a mobile water treatment unit and a mobile laboratory, have been completed and are now available commercially.

The mobile incineration system is designed to EPA's PCB destruction specifications to provide state-of-the-art thermal detoxification of long-lived, refractory organic compounds, as well as debris from cleanup operations. Hazardous substances that could be incinerated include compounds containing chlorine and phosphorus -- for example, PCB's, kepone, dioxins, and organophosphate pesticides, which may be in pure form, in sludges, or in soils.

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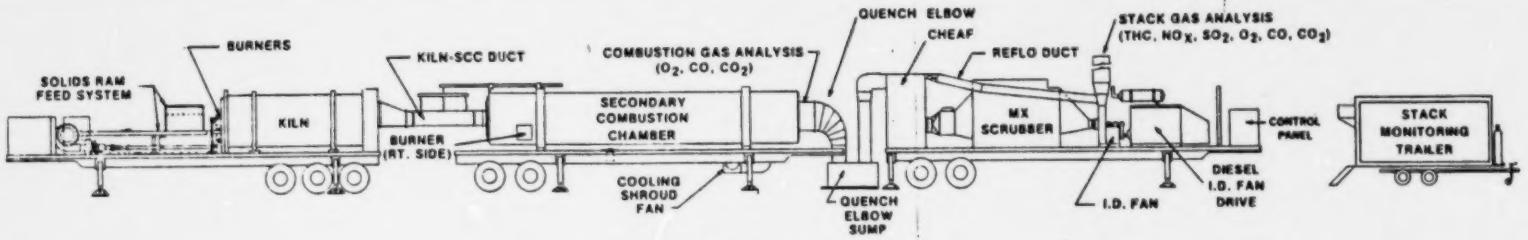
A 15-hour test burn with fuel oil has been completed, and the system has undergone priority modifications identified during this burn. The system is currently undergoing the final stages of preparation for a "PCB Trial Burn." The "PCB Trial Burn," scheduled during the summer of 1982, represents a systematic approach to evaluate and demonstrate the incinerator's ability to meet and exceed the performance requirements established by Federal, State, and municipal regulations. After the trials, the system will be demonstrated at several hazardous waste sites around the country.

To date (Spring 1982), EPA, through the Oil and Hazardous Materials Spills Branch at Edison, New Jersey, has spent $2.2 million on the design, development, testing, and permitting of the mobile incinerator. Fabrication costs of a similar mobile incineration system (without development and testing expenditures) is estimated to be $1.1 million.

For further information, contact Mr. Frank Freestone, Dr. John Brugger, or Mr. James J. Yezzi, Jr., Municipal Environmental Research Laboratory, Oil and Hazardous Materials Spills Branch, Edison, New Jersey. Telephone numbers are: (201) 321-6632 (commercial) or 340-6632 (FTS).



EPA MOBILE INCINERATION SYSTEM

to demonstrate the detoxification of dioxin-contaminated soil by thermal incineration; (2) Kin-Buc landfill in Edison, New Jersey, to destroy 300 barrels of PCB-contaminated oily leachate; and (3) Hyde Park, New York, to demonstrate the thermal destruction of dioxin-containing sludges at a landfill site. After testing, the plans, specifications, and other information will be made available publicly for the purpose of encouraging commercialization of the new technology.

Modular Transportable Incineration System

An initial study has been proposed to determine the utilization of a modular transportable incineration system. The purpose of the study is to examine the technical, administrative, and economic feasibility of the use of modular incineration systems for destruction of toxic organic wastes at Superfund sites in the United States. Such wastes may include materials such as dioxins, organophosphate and carbamate pesticides, PCB's, and other organic substances recognized as highly toxic. The modular system would have a capacity 5-10 times the existing EPA Mobile Incineration System, and would be assembled from commercially available components (taking maximum advantage of existing equipment and technology) at a site selected to be within an economic transport radius of several sites needing cleanup. At the conclusion of cleanup operations, the system would be disassembled and moved to another location, thus avoiding public reaction to a permanent hazardous waste disposal facility.

This soon-to-be-started feasibility study will address the following major areas:

- System duty requirements, including examination of location and types of sites having incinerable wastes, and the characteristics of those wastes;

- Capabilities of existing transportable incineration systems, both domestic and foreign, specifically including systems currently being developed or operating in the Netherlands and Sweden. The potential for modification of domestic cement and lime kilns for use as incinerators is also to be evaluated;

- Effects of institutional requirements, such as RCRA and state permitting restrictions and examination of options for ownership (government vs. private sector);

- Process specifications, including examination of requirements for incinerating liquids and solids based upon the potential quantity of each;

- Cost analysis, including an examination of the effects of process selection, mode of transport (rail, barge, highway), capacity, energy requirements, and duration of operation;

- Comparison of the treatment requirements to the capabilities of existing facilities.

Groundwater

The contamination of groundwater is a common occurrence at superfund sites. The solution to this problem is often difficult and costly. Control of groundwater pollution usually starts with the elimination of the source of pollution. Several approaches are then available to control the plume of contamination and to remove the contaminants. Pumping and treatment is often practiced. This technique is often expensive and can require long periods of time to cleanse the aquifer. Pumping can also be used to control the migration of the plume. Clean or contaminated water can be pumped depending on the approach used. In some cases, pumping, treatment of the water, and reinjection have been practiced, the idea being to enhance and speed up the flushing of the contaminants from the system.

Subsurface drains and cutoff trenches have been utilized to intercept the groundwater. Barriers, such as grout curtains and slurry trenches, have been used to isolate the source of pollution or direct and divert groundwater. The diversion may be of uncontaminated water away from a source or the control of contaminated water.

Some of the more innovative techniques under consideration are in situ biological reclamation and chemical treatment. In both cases, agents are introduced into the aquifer to enhance the degradation of the polluting material.

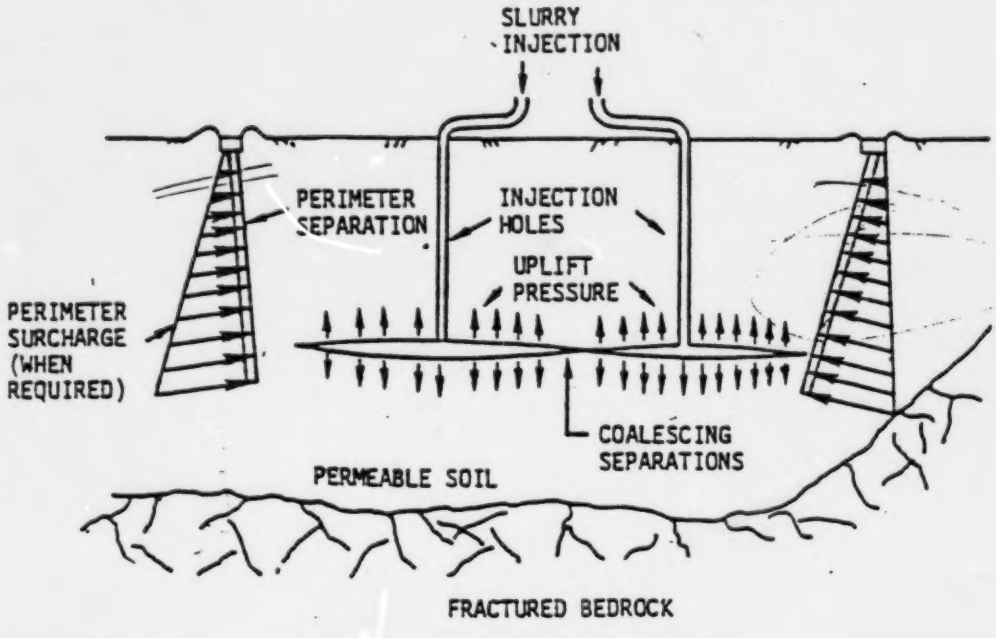
At this time I would like to report on a barrier technique that we field-tested with partial success.

Block Displacement Method

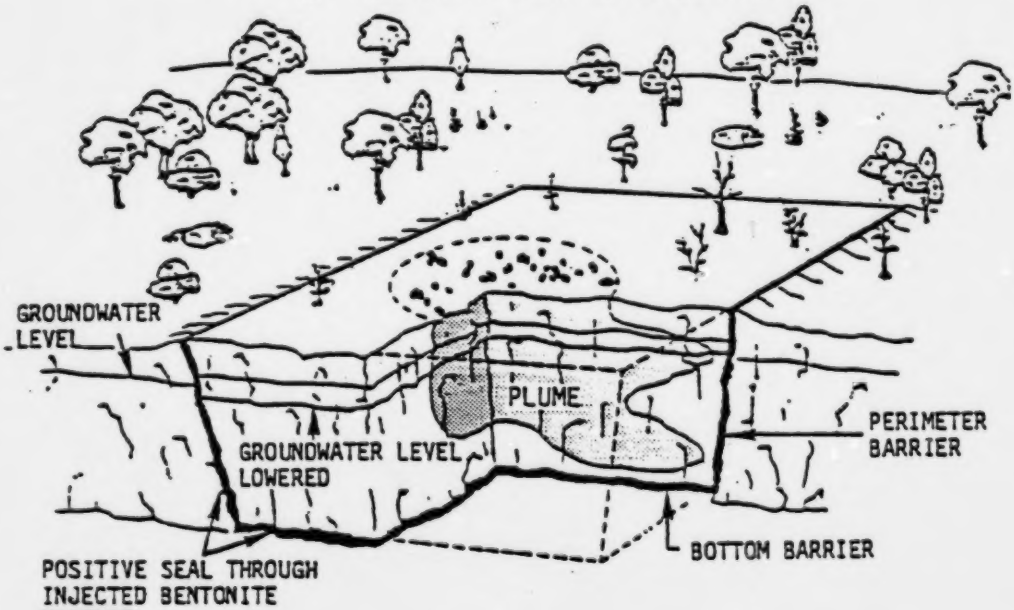
The Block Displacement Method (BDM) is a new method proposed for complete in situ isolation of contaminated earth materials (Figure 2). The method involves vertically displacing a mass of contaminated earth, and in so doing, placing an "impermeable" barrier at the bottom and sides of the mass. The barrier is formed by pumping slurry composed of soil, bentonite, or other suitable material into a series of notched injection holes. A perimeter separation is constructed using one of several techniques including thin slurry wall, vibrating beam, or a drill notch and blast technique. Once separation has occurred, the separation is surcharged with slurry to ensure a favorable horizontal stress field. The perimeter separation must be constructed at a slight angle inward toward the block center.

The bottom barrier is formed by drilling injection holes to a desired depth of the barrier below the waste. The base of the injection holes is then notched by slurry injection in a horizontal plane. Continued pumping of slurry under low pressure produces a large uplift force against the bottom of the block and results in vertical displacement of the block proportional to the volume of slurry pumped.

The BDM was field-tested near Jacksonville, Florida, in 1982. A block 60 feet in diameter and 23 feet deep was selected for the test. The site was located in uncontaminated ground adjacent to a contaminated



a) CREATING THE BOTTOM SEPARATION



b) CONFIGURATION OF FINAL BOTTOM AND PERIMETER BARRIERS

Figure 2. Block displacement method.

site. The area was relatively flat and composed of marine sediment of silty sand in excess of 100 feet overlaying limestone bedrock. The groundwater level is normally 2 to 5 feet below the surface and a hard pan layer exists at a depth of approximately 20 feet. The perimeter separation was made using a notch and blast technique. Six-inch diameter holes were drilled on the perimeter at 6-foot intervals. Each hole was notched from top to bottom. Then an 18-inch, 5-foot high concrete forming tube was placed over each hole and filled with a high density slurry. All 32 perimeter holes were loaded with prima cord and blasted simultaneously. Connecting fractures were observed at the surface.

Within the circle, seven injection holes were drilled 23 feet deep and cased with 6-inch PVC pipe and cemented in place. Horizontal notches were cut at the base of the holes with a slurry jet notching tool. Slurry was then injected into the holes. Slurry connection between holes was observed after approximately 500 gallons of slurry had been pumped into the central injection hole. Once separation between holes was achieved, block displacement proceeded over a 2-week period by pumping approximately 2 yards per hour alternately into each injection hole. A resulting upward displacement of the block occurred.

In total, the block was displaced upward approximately 11 inches at its highest point and tilted approximately 1 degree from horizontal. A crescent-shaped portion of the block was sheared free of the upward-moving block and did not move significantly. The block area near the perimeter lagged the main portion of the block by 3-6 inches in upward displacement. The crescent-shaped shear zone and perimeter displacement lag were attributed to an incomplete fracturing and freeing of the block around the perimeter.

Thin-walled tube soil samples were retrieved and geophysical site surveys were conducted several weeks after the block displacement. Data collected indicated that the clay barrier material thickness generally corresponded to the measured upward displacement of the block of earth. Observations also suggested strongly that unexpected geologic details of the site interfered with accomplishment of the barrier placement exactly according to the design plan.

This field test showed that a bentonite clay slurry could be injected below a site and uplift would occur. The perimeter barrier construction technique used was unsatisfactory. Other perimeter construction methods should be used in this type of geologic material.

Conclusion

In summary, the EPA Office of Research and Development is attempting to respond to a critical need of the Superfund Program, i.e. reliable and cost-effective control technology. Never before has the need been so great for quick answers to complex problems. In the short run, we are being faced with utilizing well recognized engineering techniques that have been used in the past for other purposes and must be adopted to the uncontrolled waste site problem. In many cases these techniques are unproven and only through their actual utilization can we determine their effectiveness, advantages, and weaknesses. In the long run, new and innovative techniques may come forth and take their place in our arsenal of weapons to clean up hazardous waste sites.